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ABSTRACT

The main problem addressed in this paper is how to help learners construct knowledge in exploring hyperspace provided by existing hypermedia/hypertext-based resources on the World Wide Web. Knowledge construction involving reflection needs an awareness of exploration goals, i.e., the reasons why learners have explored Web pages. The authors designed a learning tool called interactive history, which enables learners to annotate their exploration history with exploration goals arising from visiting Web pages. It also generates a knowledge map from the annotated exploration history, which spatially represents the semantic relationships among the Web pages explored. The results of a case study indicate that the interactive history promotes goal-aware exploration and reflection, particularly in a more complicated hyperspace. (Author/MES)

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Goal-Aware Exploration Makes Learning in Hyperspace Constructive

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Abstract: The main problem addressed in this paper is how to help learners construct knowledge in exploring hyperspace provided by existing hypermedia/hypertext based resources on the Web. The knowledge construction involving reflection needs an awareness of exploration goals, which mean the reasons why learners have explored web pages. We have accordingly designed a learning tool called interactive history, which enables learners to annotate their exploration history with exploration goals arising from visiting web pages. It also generates a knowledge map from the annotated exploration history, which map spatially represents the semantic relationships among the web pages explored. The results of a case study indicate that the interactive history promotes goal-aware exploration and reflection particularly in a more complicated hyperspace.

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Introduction

Existing hypermedia/hypertext based resources for learning/education on the Web generally provide learners with hyperspace where they can explore the web pages by following the links among the pages to learn the domain concepts/knowledge in a self-directed way. The exploration often involves constructing knowledge from the contents that have been explored, which would enhance learning (Kashihara, Ujii, and Toyoda, 1999; Thuering, Hannemann, and Haake, 1995). However, learners often fail in knowledge construction since what and why they have explored so far become hazy as the exploration progresses. The constructive learning accordingly requires reflection on the exploration process (Tauscher and Greenberg, 1997; Thuering, Hannemann, and Haake, 1995).

Having a careful consideration of exploration process in hyperspace, we have designed a learning tool called interactive history for constructive learning with existing web-based resources, and suggested that the constructive learning involving reflection particularly needs an awareness of exploration goals, which mean the reasons why learners have explored, since how to shape a knowledge structure in hyperspace is greatly dependent on the exploration goals (Kashihara, Hasegawa, and Toyoda, 2000). In order to enable a goal-aware exploration, the interactive history accordingly allows learners to annotate their exploration history with exploration goals arising from visiting web pages. The annotated exploration history also allows them to rethink and reorganize their exploration process that has been carried out. In addition, the interactive history generates a knowledge map from the annotated exploration history, which map spatially represents the semantic relationships among the web pages explored. The knowledge map intends to facilitate reflection on knowledge that has been constructed during exploration.

This paper demonstrates the interactive history, and describes a case study whose main purpose was to analyze the utility of the interactive history. In this study, we observed an intensive rethink about exploration process including exploration goals particularly in a more complicated hyperspace. The results indicate that the interactive history facilitates goal-aware exploration and reflection for constructive learning in hyperspace.

Exploration in Web-based Learning Resource

In this paper, we consider learners who attempt to learn domain concepts and knowledge in a constructive way. Some learners may not make the cognitive efforts of knowledge construction. In this case, they may only browse or surf in hyperspace. Supporting such browsing or surfing is out of our scope.

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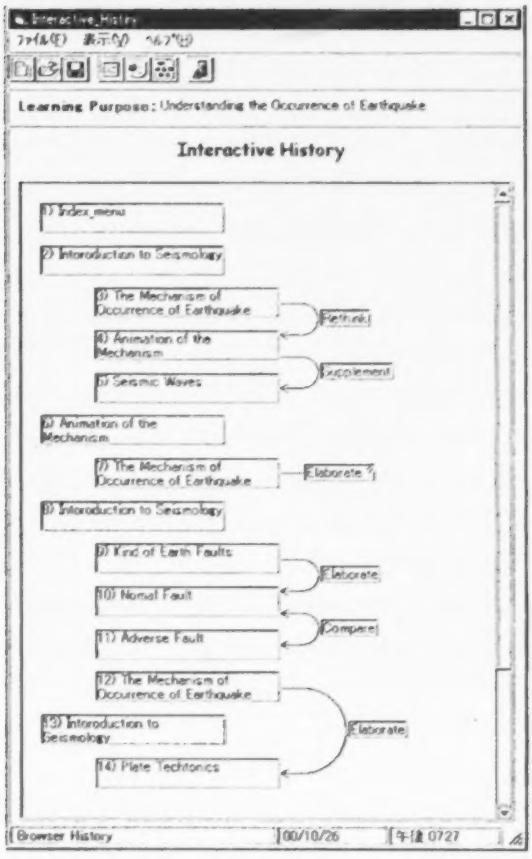

Figure 1: Annotated Exploration History.

Primary Exploration Process

In hyperspace provided by existing web-based learning resources, learners generally start exploring with a learning goal. The movement between the various pages is often driven by a local goal called exploration goal to search for the page that fulfills it. Such exploration goal is also regarded as a sub goal of the learning goal. We refer to the process of fulfilling an exploration goal as primary exploration process. This is represented as process from the starting page where the exploration goal arises to the terminal page where it is fulfilled.

An exploration goal may have several terminal pages with one starting page. Exploration goal, represented as verb, signifies how to develop or improve the domain concepts and knowledge learned at the starting page. We currently classify it into six goals: *Supplement*, *Elaborate*, *Compare*, *Justify*, *Rethink*, and *Apply*.

An exploration goal arising from visiting a page is not always fulfilled in the immediately following page. In such case, learners need to retain the goal until they find the appropriate terminal page/s. While searching for the fulfillment of the retained goal, it is possible for other exploration goals to arise. The need to retain several exploration goals concurrently makes the knowledge construction more difficult to achieve.

The exploration process can be modeled as a number of primary exploration processes. Let us give an example where a learner uses a hyperdocument on the Web with the learning goal of understanding the occurrence of earthquake. In this example, he/she explores a number of the web pages with various exploration goals. Figure 1 gives the exploration history, which shows the sequence of the pages visited and primary exploration processes. For example, he/she visited the page *Animation of the Mechanism* in order to rethink the description in the page *The Mechanism of Occurrence of Earthquake*. He/she then visited the page *Seismic Waves* since he/she did not know the meaning of the term used in the previous page.

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Knowledge Construction

In constructing knowledge, learners would make a semantic relationship among the domain concepts/knowledge in the starting and terminal pages of each primary exploration process, and then combine each semantic relationship to integrate a number of primary exploration processes (Thuering, Hannemann, and Haake, 1995). In educational hypermedia/hypertext systems with concept maps representing domain concepts to be learned, learners can derive such semantic relationship from the maps. Most existing web-based learning resources, on the other hand, do not specify the semantic relationship. The learners accordingly need to identify it by themselves.

The semantic relationship would be shaped according to the exploration goal. For instance, a learner may search for the meaning of an unknown term to supplement what is learned at the current page or look for elaboration of the description given at the current page. Each exploration goal provides its own way to make relationship between the starting and terminal pages (Kashihara, Ujii, and Toyoda, 1999). The knowledge construction process accordingly requires an awareness of the exploration goals.

Reflection

It is often difficult for learners to construct their knowledge since the primary exploration processes including exploration goals, which have been carried out so far, become hazy as the exploration progresses. Reflection on the primary exploration processes is accordingly involved in completing the knowledge construction (Thuering, Hannemann, and Haake, 1995). In the reflection, it is necessary for learners to rethink what and why they have explored. They should be particularly aware of the primary exploration processes. They may also need to reorganize the exploration process, which has been carried out (Kashihara, Ujii, and Toyoda, 1999).

Interactive History

The above consideration indicates that a goal-aware exploration should be encouraged, and that rethinking and reorganizing the exploration process that has been carried out should be supported. In order to give learners awareness of exploration goals and primary exploration processes, the interactive history system provides an exploration history that is annotated with exploration goals. It also provides a knowledge map, which visually represents relationships among the primary exploration processes, to help the learners to reflect on knowledge structure that has been constructed.

The interactive history system first enables learners to annotate an exploration history, which includes web pages sequenced in order of time they have visited, with primary exploration processes. In order to help learners note down the exploration goals, the system provides them with a list of exploration goals, and requires them to select one from the list when an exploration goal arises. The learners are also asked when they find the terminal page/s. The interactive history system annotates the exploration history with the information noted down. The annotated exploration history enables the learners to retain the primary exploration processes. The learners are also enabled to modify/delete the primary exploration processes and to add new primary exploration processes after exploring hyperspace. Such manipulation allows them to reorganize their exploration process.

The interactive history system second transforms each primary exploration process, which is extracted from the annotated exploration history, into a visual representation. It then combines each visual representation to generate a knowledge map. The knowledge map does not obviously represent the contents included in the explored pages, which may be summarized by the page titles. However, this summarized information would be substantially fruitful for learners to reflect on what they have learned.

Annotated Exploration History

In the interactive history system, learners use Web browser to explore hyperdocuments on the Web with one learning goal. When they want to set up an exploration goal in visiting a page, they are required to mouse-click the corresponding page in the *Annotated Exploration History* window. The *Exploration Goal Input* window then appears as shown in Figure 2. The learners can select one corresponding to the goal from the exploration goal list in the window. The page visited currently in the browser is also recorded as the starting page of the exploration goal. After inputting the exploration goal, the window disappears. In the hyperdocuments, the title tags of the pages do not always represent the contents of the pages. If the learners want to change the page titles, they can input new titles in

the *Exploration Goal Input* window. The pasted information and the changed page titles are also used in the annotated exploration history.

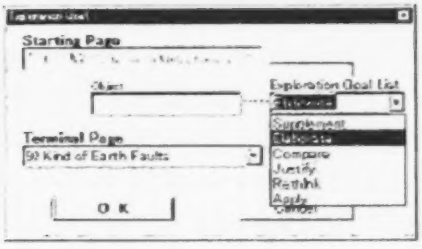

Figure 2: Exploration Goal Input.

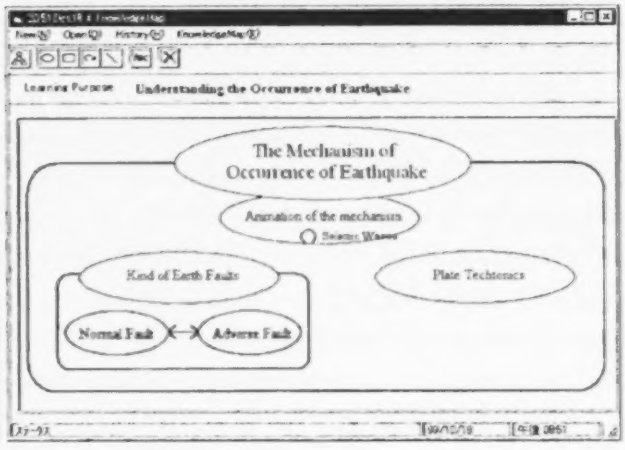

Figure 3: A Knowledge Map

When the learners find a terminal page of the exploration goal, they are required to mouse-click the exploration goal in *the Annotated Exploration History* window. The *Exploration Goal Input* window then appears. They can input the terminal page by dragging the title of the terminal page and pasting into the terminal page section in the window.

Using the information inputted from the learners, the system generates the annotated exploration history as shown in Figure 1 ...s that the primary exploration processes can be viewed clearly. In the annotated history, each page has its page title. The starting page of each goal is linked with the corresponding terminal page/s. There may be some primary exploration processes without terminal pages since they have not been found yet. The learners can look at the annotated exploration history on their demand during exploration.

Directly manipulating the annotated exploration history, learners can reconstruct their exploration process. Each manipulation is done by means of mouse-clicking/dragging parts of the primary exploration processes. There are three basic manipulations: deleting and changing exploration goals/links between starting and terminal pages, and adding new primary exploration process.

Knowledge Map

In order to make the knowledge map understandable, we have defined the correspondence of an exploration goal to a visual representation of the relationship between the starting and terminal pages. For example, an exploration goal to *Elaborate* is transformed into a set that visualizes the starting page as a total set and the terminal page as the subset. An exploration goal to *Compare* is also transformed into bidirection arrow between the starting and terminal pages. Following such correspondence, the system generates a knowledge map by combining visual representation of each primary exploration process in the annotated exploration history. The knowledge map generation is executed on learners' demand before/after manipulating the annotated exploration history.

Figure 3 shows an example of the knowledge map that is generated from the annotated exploration history shown in Figure 1. Viewing this map, the learner can recall that he/she elaborated *The Mechanism of Occurrence of Earthquake* by exploring *Kind of Earth Faults*, and that he/she furthermore elaborated it by comparing *Normal Fault* and *Adverse Fault*.

Case Study

The main goal of the case study was to analyze the utility of the system and to ascertain if the interactive history system facilitates reflecting on exploration process compared to learning without the system. We also

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prepared two web-based learning resources, which had comparatively simple (learning resource 1) and complicated hyperspace (learning resource 2), and ascertained in which resource the interactive history system enhances its own utility and facilitates reflection for knowledge construction more successfully. Subjects were thirteen graduate and undergraduate students in science and technology.

We set four conditions, which were (1) learning in the learning resource 1 with the system (Simple-With), (2) learning in the learning resource 1 without the system (Simple-Without), (3) learning in the learning resource 2 with the system (Complicated-With), and (4) learning in the learning resource 2 without the system (Complicated-Without). Subjects were provided with Internet Explorer as web browser under each condition. In this study, each subject learned one learning resource with the system, and learned the other without the system. In other words, he/she was assigned two conditions, which were Simple-With and Complicated-Without (or Simple-Without and Complicated-With). The assignment of the conditions was counterbalanced.

Before learning, subjects were given a learning goal for each learning resource. Under Simple-With or Complicated-With, they were also given the explanation about how to use the interactive history system, and were asked to try it in a sample learning resource whose hyperspace is simple. They were then asked to explore hyperspace with or without the system to accomplish the learning goal. The time of learning in each condition was limited to thirty minutes.

In this study, the utility of the system was analyzed with the dispersion of pages visited, the number of revisit per page (Tauscher and Greenberg, 1997), the number of primary exploration processes executed, and the number of revisiting pages that were included in the primary exploration processes. Comparing the averages of them under Simple-With and Simple-Without or under Complicated-With and Complicated-Without, we evaluated the utility of the interactive history system.

The results of the study are as follows. The average number of revisit per page on Complicated-With (1.83) was larger than that on Complicated-Without (0.89) although there was a slightly difference between Simple-With (1.95) and Simple-Without (2.07). The average dispersion of pages visited on Complicated-With (0.35) was lower that that on Complicated-Without (0.53) although there was a slightly difference between Simple-With (0.34) and Simple-Without (0.32). These results indicate that the interactive history system makes exploration more intensive in a more complicated hyperspace.

We further analyzed the utility of the interactive history system on Simple-With and Complicated-With. The average numbers of starting and terminal pages on Simple-With and Complicated-With corresponded to about half of the average numbers of pages visited (54.8% on Simple-With and 51.0% on Complicated-With). In other words, half of the visited pages were related to the primary exploration processes. The average numbers of revisiting the starting and terminal pages on Simple-With and Complicated-With accounted for 74.5 % and 79.9 % of the whole revisits. These ratios were very high.

From these results, we observe that goal-aware exploration and intensive revisits to the web pages in relation to the primary exploration processes were done particularly in a more complicated hyperspace. This suggests that the interactive history can promote reflection on primary exploration processes and their relationships. Although a more detailed investigation is needed, we guess that the aim of such reflection is to construct knowledge, which fulfills a learning goal, because of the high ration of revisits to primary exploration processes.

Discussion

Let us now discuss several points to notice in utilizing the interactive history. The interactive history system requires learners to input information about primary exploration processes that have been carried out. Such inputting, in addition, requires a meta-cognitive skill that is indispensable for managing knowledge construction process in existing web-based learning resources. The interactive history system could distract learners, who do not have it, from their learning tasks in hyperspace. We believe, however, it is educationally important to train the learners to improve the meta-cognitive skill so that they can learn in the Web. The interactive history can be viewed as a potential tool for this training.

Before using the interactive history system, in addition, learners need to know how to interpret the visual representation used for the knowledge mapping. In order to explain it, the interactive history system demonstrates few examples of annotated exploration history and knowledge map before starting the actual learning support.

Let us next compare with related work to consider the usefulness of the interactive history. The general Web browsers such as Netscape and Internet Explorer enable learners to revisit Web pages with back buttons and browsing history. However, these facilities do not always make the retention of their exploration processes easy. In particular, the browsing history provides no information of primary exploration processes that have arisen.

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As the retention support, there are several kinds of annotation systems that allow learners to take a note (Brusilovsky, 1996). However, there is little discussion of what kind of annotation should be done for the success in constructive learning. In the interactive history, we claim that the reasons why learners search for the next pages should be particularly noted down.

Current work on adaptive hypermedia/hypertext systems has often provided spatial maps and concept maps as reflection support, which are originally used as navigational aid. Spatial maps can inform the learners where they are, what they explored, and to what extent they explored (Domel, 1994). However, the reasons why they visited are not clearly shown. Concept maps are more helpful for learners since the direction of knowledge construction is visible to them (Gaines and Shaw, 1995). However, learners, who particularly have higher capability of constructive learning, may identify semantic relationships among the domain concepts explored in a learner-centered way, which relationships may be different to those defined in the concept maps (Thuering, Hannemann, and Haake, 1995). In other words, they do not always construct the same knowledge structure as the structure of domain concepts that the designers of concept maps make.

The interactive history, on the other hand, can provide learners with a more proper support since it enables learner-centered exploration and generates a knowledge map according to their exploration process. In addition, the interactive history can also provide the reflection support even for most existing web-based learning resources of which concept maps are not prepared and even in ill-structured domains of which concept maps cannot be defined.

Conclusions

This paper has claimed that constructive learning with existing web-based resources requires learners to develop an awareness of not only what but also why they have explored. It has also stated that supporting it requires a learning tool promoting the knowledge construction involving reflection on their exploration process.

This paper has also demonstrated the interactive history, which encourages learners to do a goal-aware exploration. It enables them to annotate the exploration history with the exploration goals to rethink and reorganize their exploration process. It also generates a knowledge map from the annotated exploration history, which allows the learners to reflect on what they have constructed during exploration.

In addition, this paper has described an evaluation of the interactive history system. Although we need a detailed evaluation with more subjects, the results indicate that the system promotes the reflection on exploration process particularly in a complicated hyperspace.

In the future, we will have a more detailed evaluation. We would also like to classify exploration goals in detail to represent learners' exploration process more precisely.

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